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Enhanced Query Data Recorder – A Next Generation Flight Recorder Built Around The iNET Standards

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The Enhanced Query Data Recorder (EQDR) has been developed under the Test Resource Management Center's (TRMC) Spectrum Efficient Technologies (SET) Test and Evaluation Science and Technology (T&E S&T) program. The EQDR is a network flight recorder built around the iNET standards and which is intended to meet the future needs of the networked telemetry environment. The EQDR is designed to support the "fetch" of recorded test data during a test without interruption to the ongoing recording of data from the test article vehicle network.
The key benefits of the network data recorder as implemented in the EQDR are increased flexibility and efficiency of test in an environment with increasing demands on spectrum available for telemetered data. EQDR enables retrieval of individual recorded parameters on an as-needed basis. Having the flexibility to send data only when it is required rather than throughout the duration of the test significantly increases the efficiency with which limited spectrum resources are used. EQDR enables parametric-level data retrieval, based not only on time interval and data source, but also on the content of the recorded data messages. EQDR enables selective, efficient retrieval of individual parameters using indexes derived from the actual values of recorded data.

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ENHANCED QUERY DATA RECORDER – A NEXT GENERATION FLIGHT RECORDER BUILT AROUND THE INET STANDARDS

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KEY WORDS

Network data recorder, flight recorder, iNET, spectrum efficiency, enhanced query data recorder

INTRODUCTION

The T&E community has identified a number of use cases that call for the ability to "fetch" data on demand from a test article, without interrupting the ongoing recording process. In response to this need, the Test Resource Management Center's Spectrum Efficient Technologies Test and Evaluation Science and Technology program is sponsoring development of the Enhanced Query Data Recorder, a network data recorder (NDR) that is intended to meet the future needs of the networked telemetry environment. The EQDR is a network data recorder that enables retrieval of individual recorded parameters on an as-needed basis, in response to queries from the ground, and supports concurrent recording of all data on the test article bus.

This paper describes the design of EQDR and the benefits of selective data storage and retrieval in the application of networked telemetry.

T&E NEED

As described in the *iNET Needs Discernment Report* (2004), the T&E community has identified several use cases that highlight the need for a network data recorder that can retrieve and record data concurrently. The first use case describes the T&E need to "fetch" data from the test article on demand. This underlying need applies to many of the remaining 51 use cases, as well. The capability to pull data from an onboard flight recorder and transmit those data to the ground during flight test ensures that the test engineer can receive all required test data. This benefit is significant to the T&E community. The need to fetch data from the test article may arise for several reasons, including data dropouts and changes in test mode, such as inter-maneuver periods and non-nominal/emergency phases of flight. The following paragraphs describe these reasons in more detail.

Data dropouts. Telemetry data dropouts are unavoidable in T&E, especially in the aeronautical test community where aircraft maneuvers result in the degradation of received signals. In addition, various radio frequency (RF) environments encountered during a flight test (e.g., flight line, flight path over the ocean or a dry lake bed, or hilly terrain) can cause obstruction or multipath, fading, or line-of-sight signal degradation, also resulting in data dropouts. During these dropout periods, critical data are lost, and because certain short duration dropouts are not always detected during the test, erroneous interpretation of real-time data can result. Traditional flight recorders do not provide a mechanism to retrieve data to fill in these data dropouts.

Non-nominal/emergency modes. The amount of data generated on board the test article exceeds by at least an order of magnitude the amount of spectrum available to support real-time transmission of onboard sensed parameters. As a result, test engineers must choose to send only the most critical data to mission control facilities in real time, while recording the remainder of data on board for post-mission analysis. If an unanticipated or emergency mode occurs during a test event, the test engineer in mission control may want to view additional recorded data related to the observed anomaly that was recorded but not originally transmitted to ground because of spectrum limitations. Doing so may be critical in real time to ensure safety of flight or to

preclude unnecessary termination of flight test. Traditional flight recorders have no mechanism for retrieving specific measurements from the flight recorder for analysis during flight test.

Inter-maneuver periods. In accordance with current T&E operational scenarios and IRIG 106 standards, the telemetry stream transmitted from the test article to the ground is a fixed stream for the duration of the test. This fixed stream results in inefficient use of the available spectrum, especially during inter-maneuver periods when there is a minimal requirement for data to be sent to the ground beyond safety of flight data. During these periods of reduced test activity, recorded data could be retrieved and sent to the ground for analysis to ensure test objectives have been met. The IRIG 106 Chapter 10 specification does not support this capability.

Spectrum Efficiency. A corollary requirement to the need to fetch data on demand is the need to do so with maximum spectrum efficiency. Recorded data that are transmitted to the ground during flight must be inserted into the transmitted data stream and, as a result, compete with other data for very limited spectrum. Therefore, it is an inherent requirement that the flight recorder support *efficient* retrieval of specific recorded parameters. If the recorder responds to data requests with large blocks of extraneous data, along with data that are truly needed, then the retransmission of data represents a costly and inefficient use of spectrum. For spectrum efficiency, it is imperative that the network data recorder be able to store, and retrieve, data at a parametric level.

The overall benefits to the range community include more efficient use of available spectrum, increased safety of flight, more efficient use of range resources, and reduced cost of test. Existing IRIG 106 Chapter 10–compliant recorder technology does not support any of these requirements. The EQDR has been developed to fill these T&E needs.

DESIGN

A primary reason for developing a network recorder is to have the ability to retrieve previously recorded data and transmit it to the ground station without interfering with the recording of live data during the test. One key instance in which this capability adds value to T&E is during data drop out caused by the test vehicle maneuver or by other types of signal degradation. Retrieving lost data from these intervals has many benefits, including improved safety of flight. Having the ability to retrieve recorded data is only of value if sufficient bandwidth exists for its retransmission during flight, yet one of the major problems facing the T&E community is lack of spectrum available to send telemetry in real time. That problem is only exacerbated when recorded data are retrieved and added to what must be transmitted to the ground.

Because of these constraints, a network data recorder not only must be able to record and retrieve data concurrently, but also must be able to retrieve that data efficiently. Efficient data retrieval means fast data retrieval, and to an even greater extent, it means selective data retrieval. The user of the recorder must be able to retrieve only the specific parameters that are required for retransmission. The reason for this selectivity is spectrum efficiency. Because the amount of bandwidth available as a whole is constrained, the amount of bandwidth available for retransmitted parameters is even more limited. Use of this extremely limited bandwidth to

retransmit data that are not needed represents a waste of limited resources. Therefore, the NDR must be designed to retrieve very specific subsets of data. The level of specificity required for spectrum efficiency goes much beyond retrieval of data based on time periods and Internet Protocol (IP) addresses of source Data Acquisition Units (DAUs). The recorder must have a way to retrieve specific measurands of interest.

Spectrum efficiency, selective data retrieval, and rapid data retrieval were all factors in considering appropriate technologies for the EQDR. Existing flight recorder technology is robust and capable of very high data recording rates. No doubt, a developer could add an Ethernet interface to an existing flight recorder, update the system to allow for simultaneous record and retrieve, and record blocks of data, specifically Telemetry Network System (TmNS) messages as defined in the Integrated Network Enhanced Telemetry (iNET) standards, for retrieval. While this design would meet the physical and network requirements for a network recorder, it would not provide a mechanism for selective data retrieval at the level of individual measurements. In many implementations, data would be stored and retrieved as blocks of TmNS messages from multiple message sources. Even if the system were designed to retrieve only the TmNS messages generated by a single message source (TmNS DAU), the TmNS packets themselves would be composed of measurands from many sensors on board the aircraft. Retransmission of these packets in real time would include not only the few specific parameters of interest, but also all other measurements associated with that TmNS message source.

The ideal network data recorder should be able to extract individual parameters from the TmNS messages to make most efficient use of the limited spectrum available for retransmission of historical data during flight. One approach would be to design a system to record raw TmNS messages and develop software that would, on retrieval, process the TmNS packets to pull out individual measurands of interest. To perform this capability efficiently, the system would need to associate measured parameters with a specific TmNS message source (e.g., DAU). The system then could respond to a retrieval request by identifying the set of recorded TmNS messages that contain the desired data, based on message source and recording time. One could design the system to then dissect the TmNS messages to extract specific data for retransmission. A major downfall of this approach is that it requires the network recorder to keep track of which physical TmNS message sources are associated with individual sensed parameters. This tracking is challenging and cumbersome, and it would be similar to writing software to run on large networks using static IP addresses. In this approach, the system would record TmNS data messages in their raw format, and on their retrieval, it would extract individual sensed parameters from the recorded TmNS packets using post-processing software.

A more powerful and flexible approach, the one adopted for the EQDR design, is to develop a recorder that processes the TmNS data before recording. This approach offers several benefits. First, the system need not associate TmNS message source with TmNS message content. It can maintain a level of abstraction between physical instrumentation of the aircraft and the data gathered by that instrumentation. This layer of abstraction is critical for system design and maintenance. Second, the design also makes it possible to retrieve individual sensed parameters rather than larger TmNS message blocks. As the EQDR receives TmNS messages, it breaks them apart and analyzes the content of those messages. Because there are many more individual sensors on board the test article than there are TmNS DAUs, each TmNS message may contain

data measured by many individual sensors on board the test article. The EQDR stores these data independently of each other for more selective retrieval. A third, and perhaps the most powerful, benefit of preprocessing TmNS data is that it allows the EQDR to store not only measured data, but also metadata (above and beyond what is included in TmNS packet headers) associated with the measured data. While a raw TmNS network recorder could keep track of recording time and message source (TmNS source IP), the EQDR records various attributes about the data, such as minimum, maximum, and average value recorded within that time block. These attributes enable even more selective retrieval based not only on when the data were recorded, but also on the data's value.

IMPLEMENTATION

A commercial DBMS is used for the underlying storage mechanism within the EQDR. Commercial DBMSs are a very mature technology. DBMS vendors have made tremendous investments in this technology, resulting in systems that can store and retrieve massive amounts of data at the parametric level, as quickly and efficiently as possible. They handle the problem of storing and extracting selected data based on a variety of specific conditions with a high degree of efficiency. Incorporating a commercial DBMS into the EQDR as an underlying storage and retrieval mechanism reduces development time and cost and results in a higher performing and robust recorder.

The EQDR system comprises two major components. First is EQDR Recorder module, which is the actual flight recorder that sits on the test article. This consists of one or more processor boards that run the underlying system software, solid-state drives (SSDs) for data storage, and an Ethernet interface. The second major component of the EQDR system resides on the ground and consists of a user interface and application code that processes retransmission requests and queries.

SUMMARY

The key benefits of the network data recorder as implemented in the EQDR are increased flexibility and efficiency of test in an environment with increasing demands on spectrum available for telemetered data. EQDR enables retrieval of individual recorded parameters on an as-needed basis. Having the flexibility to send data only when it is required rather than throughout the duration of the test significantly increases the efficiency with which limited spectrum resources are used. EQDR enables parametric-level data retrieval, based not only on time interval and data source, but also on the content of the recorded data messages. EQDR enables selective, efficient retrieval of individual parameters using indexes derived from the actual values of recorded data.

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